# Green Lake Water Quality

*Monitoring Results*
*for Water Year 2011 at Green Lake*

*Green Lake* *Photo by Sally Abella*

Prepared for the City of Seattle
*by the King County Lake Stewardship Program*

February 13, 2011

King County

## Overview

The King County Lake Stewardship Program (KCLSP) has worked with volunteer monitors on Green Lake since 2005 to track water quality, which has been of particular interest after the alum treatment of the lake was carried out in 2004 to control phosphorus concentrations in the water column. The volunteers undergo training and use equipment owned and maintained by King County. An example of the volunteer training manual is available on-line at
http://www.kingcounty.gov/environment/waterandland/lakes/documents/manual.aspx

Two water quality sampling stations in the lake were established in 2005 and measurements were taken at both sites in the years 2005 – 2008. Beginning in 2009 and continuing through 2011, only one station was monitored for water quality, as the two stations had produced very similar results in the previous years. However, some of the year-round physical monitoring occurred from the dock at East Green Lake (Figure 1), carried out by students from Billings Middle School under the supervision of their teachers.


**Figure 1**. **Green Lake Station locations**

Green Lake is surrounded by a public park, and car-top boats can be launched at various points around the lake. It has a history of milfoil infestation, for which control efforts have been undertaken from time to time. Green Lake has also been closed to recreation for bluegreen algae (cyanobacteria) blooms several times and has been treated for nutrient reduction to control algae, including a whole-lake alum treatments in 1991 and again in 2004.

The most recent treatment had a significant impact on nutrients and immediately improved the water quality of the lake. The 2011 data indicate that this lake continues to have low to moderate productivity (lower mesotrophic) with good water quality. Information from the current monitoring project is used to assess the longevity of the alum treatment's effect.

This report refers to two common measures used to predict water quality in lakes: the Trophic State Index or TSI (Carlson 1977), and the nitrogen to phosphorus ratio (N:P). The TSI and N:P ratios are calculated from the data collected through the volunteer monitoring program. TSI values are derived by a correlation that relates measured values of several parameters such as total phosphorus, chlorophyll *a* and Secchi transparency to estimated algal biovolume, rescaling the result to a range of 0 to 100. Oligotrophic lakes, which have small amounts of algae (low productivity) and are generally characterized by clear water, have trophic state indicator values below 40. Eutrophic lakes, which have large amounts of algae (high productivity) and are generally characterized by less clear water due to the algae, have trophic state indicator values over 50. Between 40 and 50 are the mesotrophic lakes, with moderate amounts of algae and water clarity.

These numbers can be used to compare water quality over time and between lakes. Not enough data has been collected to date at Green Lake to verify an apparent trend statistically, but it appears that the productivity in lake is currently stable or even slightly decreasing over the short term.

The discussion in this report focuses on the 2011 water year, which runs from October 2010 through September 2011, with the addition of two water quality sample dates in October 2011, and compares it to past years through the TSI indicators. Specific data used to generate the charts in this report can be downloaded from the King County Lake Stewardship data website at:

http://your.kingcounty.gov/dnrp/wlr/water-resources/small-lakes/data/LakePage.aspx?SiteID=15

Or can be provided in the form of excel files upon request.

## Physical Parameters

Good precipitation and water level records were compiled for the 2011 water year. There is little variation in lake water level through the year, which does not always match the precipitation record (Figure 2). This is because the water level in Green Lake is jointly managed by Seattle Parks Department and Seattle Public Utilities.

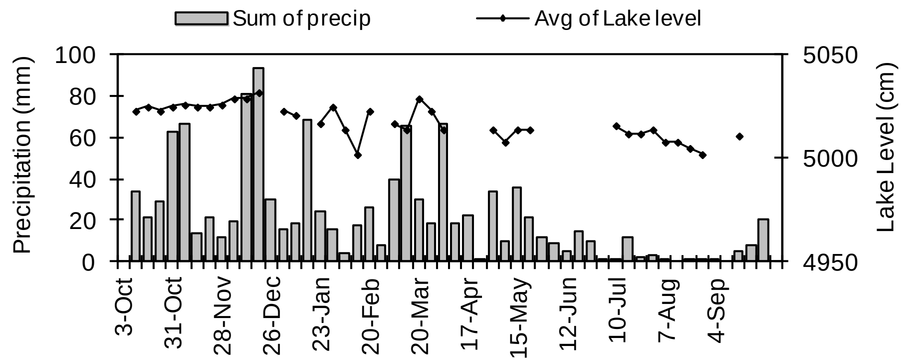


**Figure 2: Green Lake Water Level and Precipitation WY 2011**

The students from Billings Middle School under supervision of their teachers collected water level data from the dock at East Green Lake throughout the year (see map in Figure 1). Their precipitation data is collected from a rain gauge located at their school, which is nearby. Volunteer monitors collected Secchi transparency and temperature data from early May through late October at the lake station Green-1 (over the deepest part of the lake) as part of the water sample collection routine.

**Secchi transparencies** at Green-1 (Level II on the figure) ranged between 1.7 and 4.7 m from May through October, averaging 3.4 m (Figure 3), while student measurements (Level I) made throughout the year from the dock ranged between 1.5 and 4.4 m, averaging 3.3 m over the entire year and 3.0 between May - October.

There was fairly good agreement between the volunteer readings at the sampling site and the student readings at the dock, taking into account the many different factors that can bias a Secchi measurement, such as windiness, different vision, glare, and location on the lake. In addition, the shallow water column at the dock site limited the depth to which the Secchi disk could be lowered, and the depth recorded sometimes may have been a minimum value because the Secchi reached the lake bottom before it disappeared from view, which can bias the average towards a lower value and it should be viewed as the minimum average rather than the true average. Generally, Secchi readings limited by water depth will chart as a section of straight line over time, and this appeared to have happened in 2009.  However, the wide variability of the students' Secchi measurement throughout 2011 at the dock suggests this may not have been a big factor this year. There is also reasonably good agreement between the student readings at the dock and the volunteer monitor readings offshore at the water quality monitoring site during the time the two efforts overlapped.

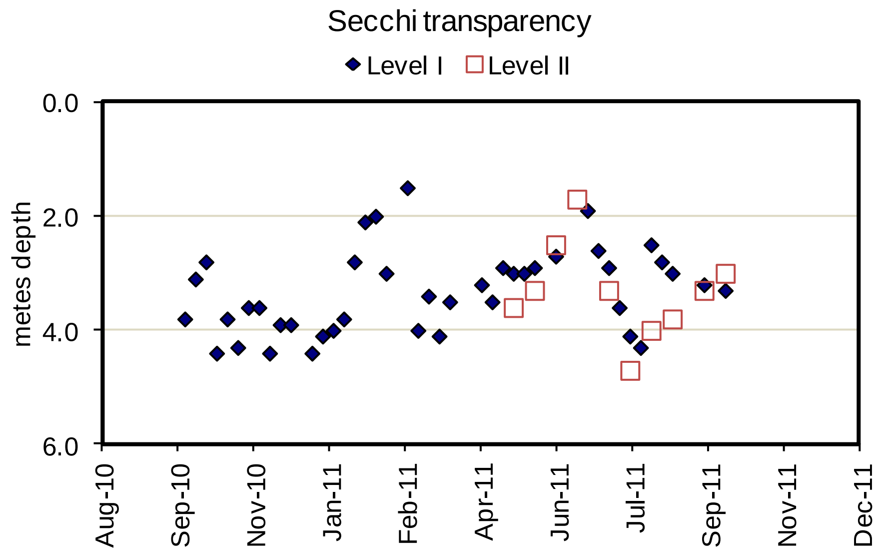


**Figure 3. WY 2011 Green-1 and East Dock Secchi transparency**

At station Green-1 surface water temperatures from May through October ranged between 13 and 22 degrees Celsius with an average temperature of 18.3 (Figure 4). At the East Dock, temperatures over the entire year ranged from 5.0 to 23.0 degrees Celsius with an annual average of 14.3 (58 degrees Fahrenheit) , while the May – October average was 19.3 (67 degrees F). Green Lake is in the lower third for summer maxima recorded among the lakes monitored by King County in 2011.

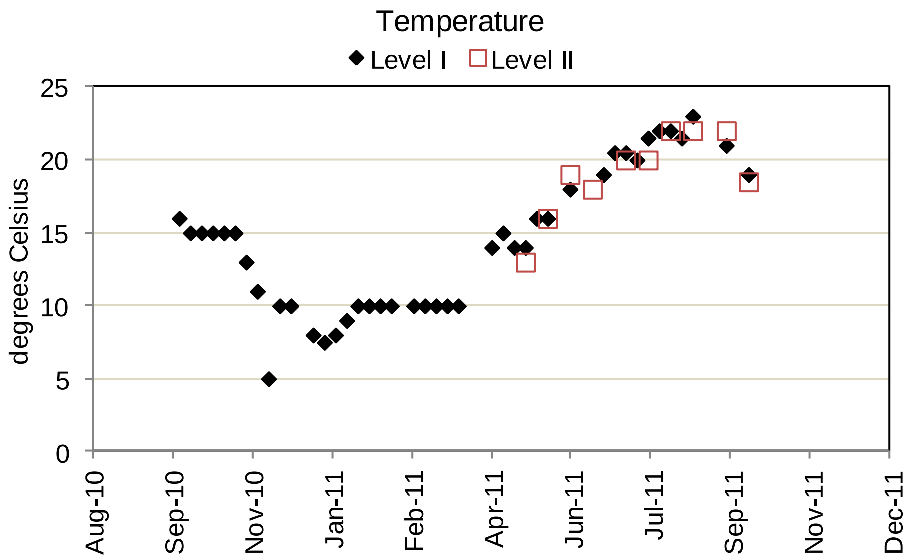


**Figure 4. WY 2011 Green-1 and East Dock Temperatures**

### *Nutrient and Chlorophyll Analysis*

**Phosphorus** and **nitrogen** are naturally occurring elements necessary in small amounts for both plants and animals. However, a variety of activities associated with residential development can increase concentrations of these nutrients beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is most often the nutrient in least supply relative to the biological demand; this means that biological productivity is often limited by the amount of phosphorus available for growth and reproduction. Increases in phosphorus concentrations can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins.

The alum treatment in 2004 at Green Lake reduced the amount of phosphorus available by binding it tightly, thus keeping it from being available for growing algae. Since 2005, water quality samples collected by volunteers between May and October have been analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth, with deeper water also sampled twice during the period each year.

At Green Lake-1 neither TN nor TP varied greatly, remaining fairly consistent through the sampling period (Figure 5). Please note that the units for TN are 10 times higher than for TP on the chart, so when values for the two parameters are close together on the graph, nitrogen is 10 times more abundant by weight.

The ratio of nitrogen (N) to phosphorus (P) can be used to determine if conditions are favorable for the growth of cyanobacteria (bluegreen algae) that can impact beneficial uses of the lake. When N:P ratios are routinely near or below 20, cyanobacteria can dominate the algal community due to their ability to take nitrogen directly from the air. From May – October total phosphorus and total nitrogen ratios ranged from 17.1 to 29.6 with an average of 23.9, with three dates having an N:P ratio just below 20 and one date at 20. This suggests that the nutrient conditions in summer may have been favorable for nuisance bluegreen growth in the lake, although weather conditions and the low concentration of available phosphorus overall may have kept significant blooms from forming.

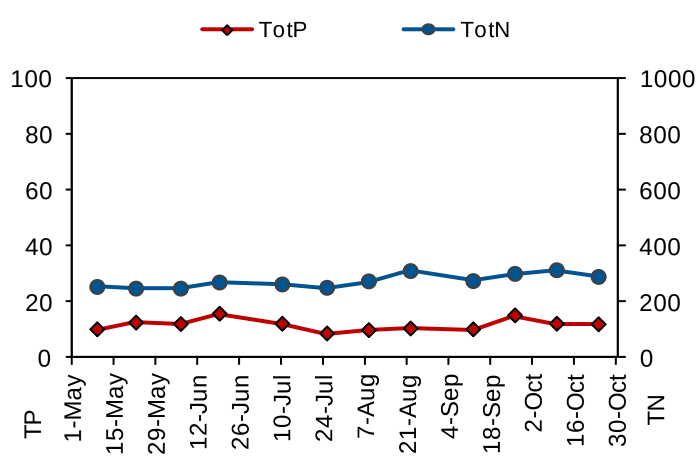


**Figure 5. 2011 Green-1 Total Phosphorus and Total Nitrogen Concentrations**

**Chlorophyll *a*** remained at relatively low values with small variations through the entire sampling period at Green-1, consistent with low phosphorus availability. Comparisons with chlorophyll data from the past are made in the following section about trophic state indicators. Pheophytin (degraded chlorophyll) was also low throughout the sampling season, though on one date in early July, it was essentially equivalent to Chlorophyll a (Figure 6). The shallow nature of the lake coupled with a relatively large fetch probably leads to some sediment resuspension and recirculation of detritus containing degraded chlorophyll from the sediments to the water column.

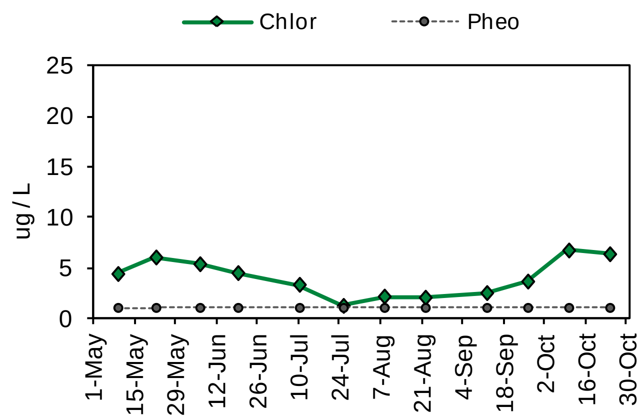


**Figure 6. 2011 Green-1 Chlorophyll *a* and Pheophytin concentrations**

The King County swimming beach program included weekly samples for the bluegreen algal toxin microcystin as well as fecal coliform bacteria concentrations, from late May through September in 2011. All spring and early summer toxin results were below the minimum detection level, but from August on small hits of microcystin were detected. All of the microcystin levels were below 1 ug/L (Washington State Department of Health recreational guidelines are 6 ug/L), but this does suggest that conditions at Green Lake can host some limited cyanobacterial growth and toxins are being produced, albeit at very low levels. King County swimming beach data can be viewed at: http://green.kingcounty.gov/swimbeach/

There were a number of samples submitted in 2011 for toxin testing under the Washington Department of Ecology algae testing program (Table 1). These were largely concentrated in early winter and again in mid to late fall after the swim beach program had finished for the year. Of these samples, two were above the Washington Department of Health suggested recreational guideline of 6 ug/L. The January 1st sample was taken during a cold period, with some of the scum observed to be frozen This appeared to be highly toxic, but had dissipated within two weeks and was not observed in a similar concentration again. The fall event followed a similar pattern, but was much less abundant overall.

Table 1. Green Lake cyanobacterial toxicity sampling under the WDOE algae program in 2011. All values in ug/L. <MDL signifies below lab detection limit. Samples above the recreational guideline are marked in red.

| Green Lake | Microcystin | Antoxin-a | Shoreline Location |
|---|---|---|---|
| 1/1/11 | **64.40** | <MDL | southeast shoreline |
| 1/12/11 | <MDL | | northeast shoreline by overflow |
| 2/7/11 | 5.77 | <MDL | near west beach |
| 6/22/11 | 1.80 | <MDL | northeast cove by boat dock |
| 10/7/11 | **9.19** | 0.09 | north shoreline by wading pool |
| 10/12/11 | 0.08 | <MDL | north shoreline by wading pool |
| 12/6/11 | 0.13 | <MDL | southwest shoreline in cat tails |

A picture of the scum during the fall period (Figure 7) shows that the accumulation was discontinuous along the shoreline.

Figure 7. Accumulation of algae along the north shoreline on October 7, 2011.

Profile data (Table 2) from Green-1 indicate that the lake was fairly well mixed thermally throughout the sampling season. Nitrogen is often found in the form of ammonia (NH3) in deep water when oxygen becomes depleted during periods of thermal stratification, thus when present, it can be used as an indicator of  low oxygen concentrations when oxygen cannot be measured directly. However, no increases in ammonia (NH3) were found in the deep water in the spring profile samples, and although during late summer there seemed to be a slight increase in ammonia, it is not enough to suggest that anoxic conditions became established in the lake. The lack of temperature differences between shallow and deep water supports the idea that thermocline development was most likely transitory, as it generally has been in the past in Green Lake.

Concentrations of phosphorus in the deep water remained roughly equivalent to shallow depths, showing that any phosphorus released from the sediments under the oxygenated conditions was likely mixed quickly through the entire water column. Chlorophyll a data indicated that algae were more or less equally distributed through the water column and remained low in concentration over all.

**Table 2. Green-1 Profile Sample Analysis Results Sample values below minimum detection level are marked <MDL.**

| Lake name | Date | Secchi | Depth | DegC | Chlor-a | Pheo | Total N | NH3 | Total P | OPO4 | UV254 | Total Alk |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green | 5/22/11 | 3.3 | 1 | 16.0 | 6.0 | <MDL | 0.248 | 0.006 | 0.0126 | <MDL | 0.032 | 33.0 |
| Green | 5/22/11 | | 3 | 15.5 | 7.1 | <MDL | 0.249 | | 0.0136 | | | |
| Green | 5/22/11 | | 6 | 14.0 | 10.9 | 1.5 | 0.259 | 0.009 | 0.0144 | <MDL | | |
| Green | 8/22/11 | 3.8 | 1 | 22.0 | 2.0 | <MDL | 0.311 | 0.009 | 0.0105 | <MDL | 0.048 | 41.3 |
| Green | 8/22/11 | | 3 | 22.0 | 2.2 | <MDL | 0.271 | | 0.0121 | | | |
| Green | 8/22/11 | | 6 | 22.0 | 2.3 | <MDL | 0.348 | 0.053 | 0.0148 | <MDL | | |

NOTE: In Table 2, <MDL stands for "below minimum detection level" of the analytical method.

The low values for UV254 indicate that the water of the lake is fairly clear and not colored by organic substances. The total alkalinity values show that the water in the lake is relatively soft, in the mid range for lakes that have been measured in King County, and only lightly buffered against pH change.

## TSI Ratings

A common method of tracking water quality trends in lakes is by calculating the "trophic state index" (TSI), developed by Robert Carlson in 1977. TSI indicators predict the biological productivity of the lake based on water clarity (Secchi) and concentrations of TP and chlorophyll *a* (see discussion in overview).

At station Green-1 in 2011 the TSI-Chlorophyll and TSI-Secchi indicators were in the lower range of mesotrophy, higher than the value for TSI-TP (Figure 8). These values have varied a little over time since alum treatment in 2004, and with the TSI-Secchi apparently the most stable since then. The phosphorus and chlorophyll TSI values have been more variable from year to year, but overall the indicators since alum treatment in 2004 have placed Green Lake in the lower range for mesotrophy. Values used for calculating the TSI values for the years 1995 – 2004 were provided by Kevin Stoops of the Seattle Parks Department and Rob Zisette of Herrera Environmental. It should be noted that while 1995 – 1996 were sampled throughout the summer, values for 2000 were based on 3 sample dates from May through July of that year. While this makes direct comparability somewhat problematic, may – July are typically months that have good conditions for algae growth and are also the time in which much recreation is occurring.

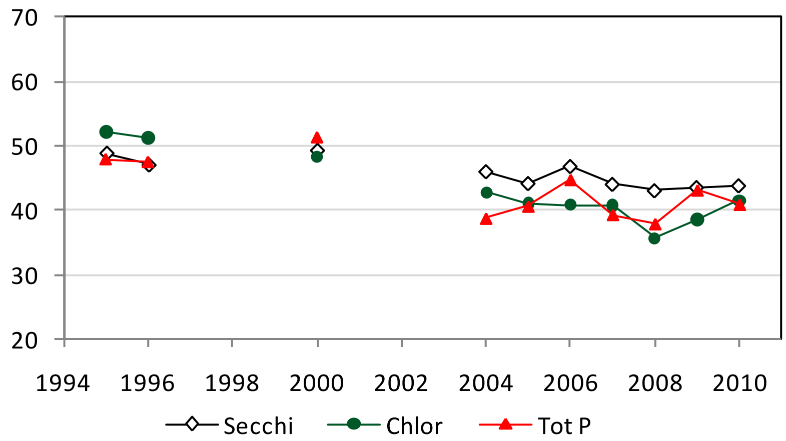


**Figure 8. Green Lake-1 Trophic State Indicators**

In addition to the volunteer monitoring conducted described in this report, the following additional monitoring data were collected at Green Lake during WY 2011 by other agencies and programs:

- King County Swimming Beach Monitoring (http://green.kingcounty.gov/swimbeach/)
- SPU continuous stage measurements (available from Seattle Public Utilities upon request)
- Water quality monitoring by Seattle Parks department (available upon request)
- Algae scum sampling done by the Washington State Department of Ecology (see Table 2) (https://fortress.wa.gov/ecy/toxicalgae/InternetDefault.aspx)

## Conclusions and Recommendations

Based on monitoring data, water quality in Green Lake has been relatively stable over the period measured since the alum treatment in 2004. The success of the second alum treatment, coupled with previous diversion actions of storm water away from the lake, has probably had much to do with the stable nutrient status of the lake over the last eight summers.

The low N:P ratios could indicate that nutrient conditions may sometimes be favorable for cyanobacterial (bluegreen algae) growth. To date, the overall low levels of available phosphorus, as well as physical conditions, have likely kept major blooms from forming. Monitoring of nutrient and chlorophyll concentrations should be continued to assess future conditions and to verify trends, in particular to continue to document the longevity of the effect of the 2004 alum treatment. If significant changes appear to be occurring, new or different management strategies should be sought and evaluated at that time.

Algae accumulations have been observed at places and times other than the monitored swimming beaches during summer. These should continue to be sampled, including submitting bloom or scum samples to the Washington State Department of Ecology's Toxic Algae Monitoring Program to determine whether or not the cyanobacteria present in the lake are producing toxins.